NASAFacts

NASA Ames Entry Aero-heating CFD Analysis

Background

In 2003, the Columbia Accident Investigation Board determined that foam debris striking the wing leading-edge upon ascent was directly responsible for the loss of the Space Shuttle Columbia and its seven crew members on February 1, 2003.

As part of its Return to Flight (RTF) efforts, NASA has developed a capability to image, analyze and repair (if necessary) damage to the Shuttle's Thermal Protection System.

The size and location of any damage to the Shuttle will be determined during day three of each mission when the orbiter does a Rendezvous Pitch Maneuver in view of the Space Station. Photos taken by astronauts on the Space Station (showing the underside of the orbiter) will be beamed back to Mission Control where the Damage Assessment Team will analyze the damage. A second set of images will be captured on the fourth day of the mission (after docking with the space station), which contain three-dimensional maps of the damage sites.

During the course of a Shuttle mission, the Damage Assessment Team, comprised of engineers from Boeing, NASA Johnson, Ames, and Langley will determine the heating and structural stresses on the orbiter at each damage site.

Computational Fluid Dynamics (CFD) experts from NASA Ames and Langley will be on called upon to analyze the more critical damage sites, and provide a higher level of accuracy to augment the information derived from engineering heating estimates.

Any necessary CFD analyses will be performed in less than 24 hours (during the fourth day of the mission) using multiple dedicated nodes on the Columbia supercomputer, taking about 3,000 processor-hours per damage site. The team will be on stand-by to analyze multiple damage sites during the course of this mission (the team was able to analyze seven sites during the STS-114 mission in July/August 2005). The site-specific re-entry heating environment will be fed into the Boeing Thermal Math Model and Finite Element analysis for determining the fitness of the tile(s) and the airframe for re-entry. Based on their analyses, the team will make recommendations to the Space Shuttle Program chair regarding the damage sites to either leave them “as-is” or repair them before reentry.

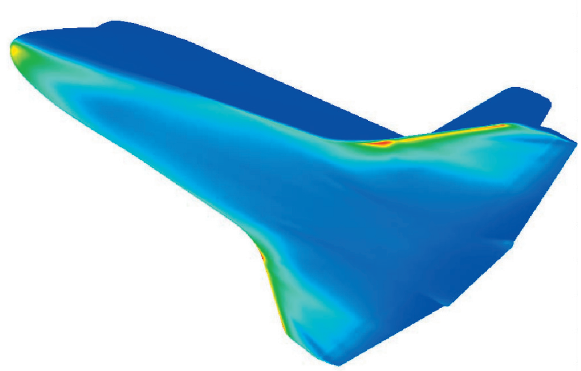

Figure 1: Heating on an undamaged Shuttle during entry into Earth's atmosphere.

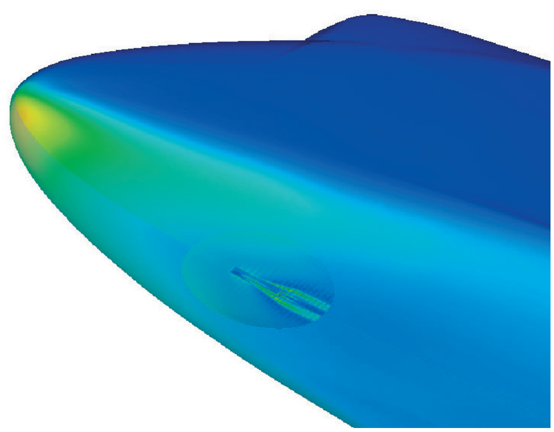

Figure 2: Heating at a damage site as simulated by NASA computational fluid dynamics software on Columbia, the world's fastest operational supercomputer. The color represents heating rate on the surface of the vehicle.

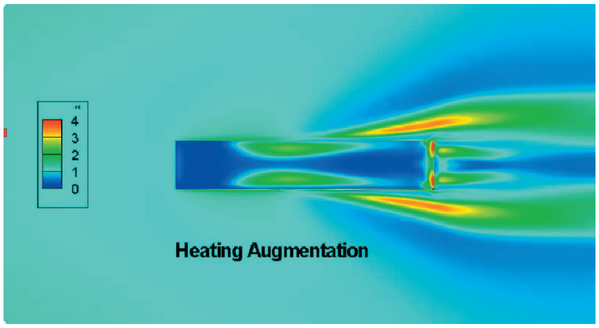

Figure 3: Damage site heating augmentation (relative to undamaged tile heating)

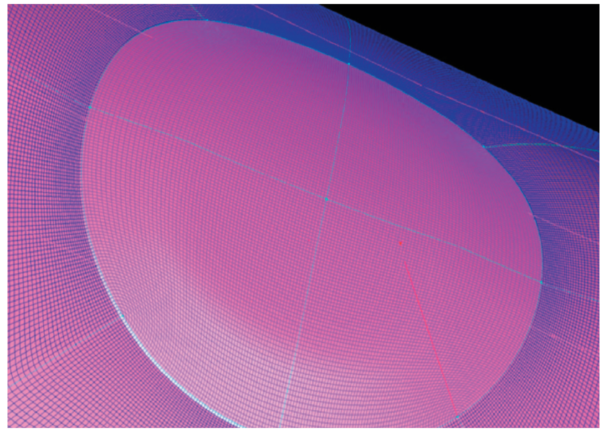

Figure 7: Heating on lip of cover plate.

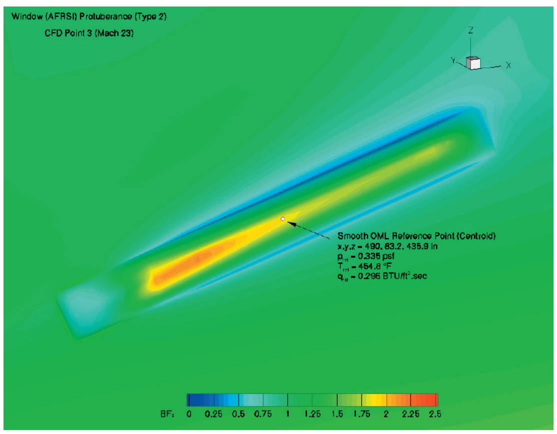

Figure 4: Heating augmentation due to the protruding blanket material near the cockpit window on STS-114.

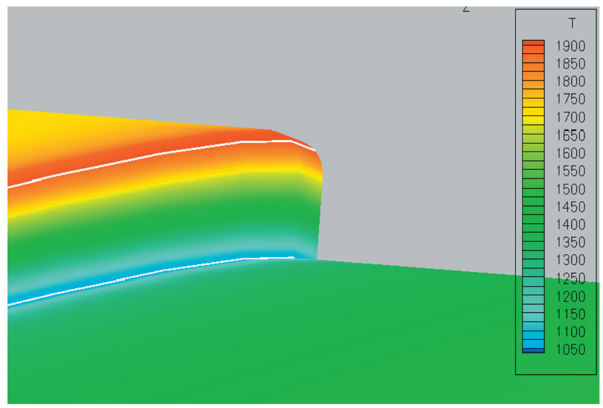

Figure 6: Cover plate (Plug) repair on wing leading edge damage.

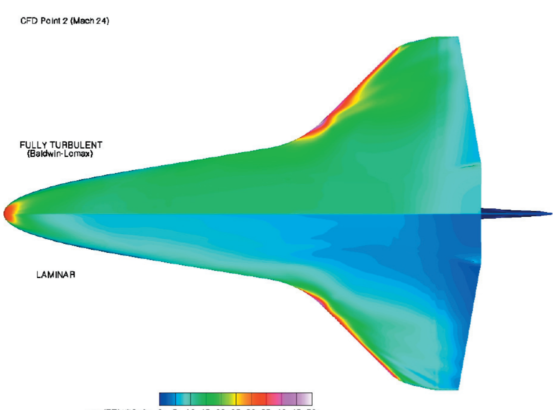

Figure 5: Effects of turbulent heating on orbiter underside and wing leading edge, driving the decision to remove the gap filler on STS-114.

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